REMARKS EXPLANATORY

AS TO

"THE SUN, PLANET AND STAR INSTRUMENT."

BY

HORATIO ALLEN, Esq.

There are some in this audience who, knowing of me in connection with bodies holding fixed position on the face of the earth, or in motion over its surface, or through its waters from continent to continent, will ask, How is it that, at this late day, Horatio Allen, of engineering antecedents, has given attention to bodies holding fixed position in the heavens or in motion through space?

I may be excused for giving a moment to this question. I am not here with any antecedents of astronomical character. I am and have been only a learner, one of the great body of learners; it was as a learner that the first movement was made in the direction that has placed me this evening before you beside this little instrument.

It is nearer sixty years than fifty, when my educational years were drawing to a close at Columbia College in this city, when its building still stood beneath the shade of the great sycamores at the foot of Park Place. I was about to close those years without the clear conceptions of the universe that I felt I ought to have attained, and I had a strong conviction that in some good degree it was because there had not been provided that aid to the mind that could be had by a presentation to the eye of the points, lines, angles and planes in which the great facts and rela-

tions exist in space, and as appeared to me could probably be presented on a scale.

My apology for occupying any time with these personal reminiscences is that they are in part explanatory of the object of the instrument.

In the study of geometry, I had had the aid of the sheets of paper on whose plane surface were presented to the eye the points, lines, angles and figures, the relation of which form geometrical knowledge. Subsequently came another geometrical subject under different circumstances; conic sections, sections of the surface of a cone by different planes, presenting an angle and the four great curve lines. These not being in the same plane could not be truly presented on the same plane surface; but no means were provided whereby the intersection of the surface of a cone and the angle and the four great curves were presented to the eye. It seemed to me that if the intersection of a cone was to be the subject of study, there should be presented to the eye the intersection as it occurs. And with this feeling I sought a turner; I had a cone made, and the intersections being made, my mind had the aid of the eye to clear conceptions on this interesting subject. Now there is no well provided school where the subject is taught which is without that aid.

STUDY OF ASTRONOMY TO BE AIDED BY PRESENTATION TO THE EYE.

In its turn came the study of astronomy, based on the knowledge of the points, lines, angles and planes as they exist in space and are observed from the surface of the earth, itself subject to a three-fold change of position, but

no provision existed whereby the aid of the eye could be had.

Of the value of that kind of aid I had had personal knowledge, and it was a direct thought that aid of that character would be of special value in attaining clear and full conceptions as to the great facts and relations in astronomy.

But it was too late for me to undertake then the difficult task. The years of avocation were at hand; but I made a promise to myself that when the years of avocation closed, if ever they did close, I would take up the subject.

Nearly fifty years passed before the years of leisure came, but I had not forgotten my promise. How could I forget it when on every clear night that I looked at the heavens, I felt that I was not seeing them understandingly?

I did not forget that long-ago promise, and the result is the instrument before you, which I do not hesitate to say, and I say it gladly in this presence, meets every condition of presenting truly to the eye every important relation that exists, and every line defined by its angles, that can be observed by angle-measuring instrument in the parallel of 40 N., very nearly the parallel of the city of New York.

Many hours are necessary to make good this comprehensive statement. I can only hope in the sixty or ninety minutes at my command to make them good in some important particulars. One circumstance is unfavorable to the object that I have in view at this time, that I am to call the attention of many, some of whom are not as near as should be, to the several parts of an instrument designed specially for the study of one person.

Being of those who consider study, personal study, the source of all well-defined attainment, it was for the table

of the learner that the instrument has been devised, and it is of necessity to that instrument that I am about to refer.

CLEAR CONCEPTIONS AS TO THE GREAT FACTS AND RELATIONS NOT DIFFICULT OF ATTAINMENT.

But before directing your attention to the instrument, I will present certain facts, which, duly considered, will meet in a great degree the general impression that clear conceptions as to astronomical knowledge are of very difficult attainment; that special antecedent knowledge, geometrical and mathematical, is necessary, and in some degree special fitness for such attainment. All such impressions will be found entirely erroneous, when the great facts on which that knowledge rests are presented as they exist in space, and the mind is aided, as it may be, by the eye.

ONLY FIVE OF SIX THOUSAND BODIES SEEN IN SPACE ARE IN MOTION.

First, I recall to your mind the fact that of the six thousand bodies to be seen in the heavens, on some nights during each year, *only six are in motion*—the moon and the five planets, Mercury, Venus, Mars, Jupiter and Saturn. All the others hold fixed position in space, and being to the unaided eye entirely without motion, *there are no motions to be studied.*

What is to be studied? Only the manner in which the relative position of lines to them from the centre of the sun, the centre of the earth and a centre of observation in a known parallel of latitude on the surface of the earth is defined, each of which can be plainly presented to the eye in the case of any one star, and that being known of one

star, the manner in which the position of lines to the fixed star is defined and is readily extended to all the others.

Next, as to the five planets that are in motion, recollect that their motions being in planes at known small angles with the plane of the earth's orbit, are readily presented when the plane of the earth's orbit is plainly and truly presented to the eye. Next, that two of the planets having their orbits interior to the orbit of the earth, the study of the phenomena of one is the study of the phenomena of the other, and the orbits of the other three being exterior of the orbit of the earth, the study of the phenomena of the one is the study of the phenomena of the other two.

Thus the attention is directed to the study of one star and the study of one interior planet and of one exterior planet, which studies consist in the *apprehension of what is plainly and truly presented to the eye.*

THE VERTICAL LINE AND THE LINE TO THE NORTH STAR ALWAYS AT COMMAND.

Next I have to remind you that there are two lines ever present to determine the position of instruments of observation, and that are of special service in determining the position of the instrument I represent, and make it possible so to place it that the facts and relations to be presented shall be truly presented.

First, the vertical line ever present by a plumb line, which, extended downward, goes to the centre of the earth, and extended in the opposite direction, is the vertical line, and which line defines, by the plane at right angles to it at the surface of the earth, the plane of observation as presented in the instrument; and, second, the line to the north star, so nearly a fixed line in space that, as observed by the

eye, not aided by the telescope, it holds and has ever held the same position; and recollect that if the line to the north star is intersected at the same point by a vertical line, and a line at right angles to the vertical line, in the plane of the two lines, the angle made by the horizontal line with the line to the north star is the angle had when from 90° is subtracted the angle of latitude of the place of the vertical line, and the plane of the three lines is in the north and south plane of the place of the vertical line.

OF THE SIX THOUSAND BODIES VISIBLE TO THE EYE, WITHOUT TELESCOPE, ONLY SIX HAVE VISIBLE SIZE, ALL THE OTHERS ARE SEEN AS BRIGHT POINTS.

Next I call attention to the fact of great interest in the construction of the instrument on a scale, viz.: that of all the bodies seen in the heavens only two have visible size to the eye without the use of the telescope—the sun and the moon. All the others are seen only as points of light, and when telescopes of great power are directed to them, all but five are still only seen as bright points of light, the five exceptions being the planets Mercury, Venus, Mars, Jupiter and Saturn.

PRACTICABILITY OF THE INSTRUMENT.

The instrument is therefore true to observation, when points are taken to present the planets, and to make the reference complete the sun is referred to by its centre point, and thus all distances are between points, and being on the same scale, relative distance can be truly presented, and as angles are the same on all scales, the practicability of the instrument for the object in view is established.

In the pamphlet which I hold in my hand of some sixty

pages is a description in detail of the construction of the instrument explaining in succession the means to be used for the object in view, and instructive as to the use to be made of the means thus provided.

Time does not permit a reference to its pages.

Description of the Instrument Commenced.

PAMPHLET DESCRIPTIVE.

The instrument, as you see, consists of a base carrying a standard 22 inches high, adjustable by screws to a vertical position. Its head-piece carries a brass rod (called the central rod) $\frac{1}{2}$ inch in diameter, 13 inches long, at an upward angle of $16\frac{1}{2}^\circ$ with an horizontal line, the line at right angles to the vertical line.

POINT REPRESENTING CENTRE OF THE SUN.

At the end of the $\frac{1}{2}$-inch rod extends a rod $\frac{1}{8}$ of an inch in diameter. On this $\frac{1}{8}$-inch rod is a circular cut $\frac{1}{10}$ of an inch from the end of $\frac{1}{2}$-inch rod, the centre line of $\frac{1}{8}$-inch rod is the extension of the centre line of the $\frac{1}{2}$-inch central rod. In the $\frac{1}{8}$-inch rod and at the circular cut is the point that represents the centre of the sun.

The instrument when studied is to hold the position at which the centre lines of the standard and of the $\frac{1}{2}$-inch central rod are in the north and south plane of the place where the instrument is studied.

When so placed, the central rod will be at an angle of $23\frac{1}{2}^\circ$ with the line to the north star, and being in the north and south plane of the place of the instrument, there is presented in the instrument a line passing through the point representing the centre of the sun, that is *parallel to the axis line of revolution* of the centre of the earth when moving in space round the centre of the sun.

POINT PRESENTING THE CENTRE OF THE EARTH.

In order to present the centre of the earth in its relation to the centre of the sun, and in its motion round the centre of the sun, the central rod carries an arm A, which carries a rod, the point of which is at a distance of 11½ inches from the centre of the sun, and the line from that point to the centre of the sun is at right angles to the axis line through the centre of the sun, as described above.

The arm A is movable on the central rod by combinations that provide that the arm is always *at right angles to the central rod*, and thus as the arm A is moved in revolution, the point of the rod carried by the arm A is always at a distance of 11½ inches from the centre of the sun, and the line from the point of the rod to the centre of the sun is always at right angles to the centre line of the central rod.

SCALE OF THE INSTRUMENT.

Now, if 11½ inches is taken to represent in the instrument the mean distance from the centre of the earth to the centre of the sun, each inch in the instrument must represent eight millions of miles, and for the reason that the mean distance from the centre of the earth to the centre of the sun is taken at 92,000,000 of miles, and 92,000,000 divided by 11½ has 8,000,000 as quotient, therefore the scale of the instrument is that each inch represents 8,000,000 of miles.

To present clearly where the point is that presents the centre of the earth, a small ball is provided to place over the point, and to present the line from the centre of the earth to the centre of the sun is provided an elastic thread that can be stretched from the centre of the earth to the centre of the sun.

The ball and thread being in place, and the arm A being moved in revolution eastward, there is presented the line in which the centre of the earth moves round the centre of the sun, and the thread from the centre of the earth to the centre of the sun being always in the same plane will enable the mind to apprehend the position of the plane known as the plane of the earth's orbit.

PLANE OF THE EARTH'S ORBIT.

As the centre of the sun is the great centre of reference in defining position, so the plane of the earth's orbit passing through the centre of the sun is the great plane of reference.

To aid the mind yet more clearly to the conception of the position in space of the plane of the earth's orbit, there is provided at the end of the central rod, a metal plate, the plane surface of which is at right angles to the centre line of the central rod.

To this metal plate is attached closely a thin sheet of paper, and the elastic thread from the centre of the earth to the centre of the sun is as near as may be in contact with the plane paper surface.

VISIBLE LINE, MATHEMATICAL LINE—VISIBLE PLANE, MATHEMATICAL PLANE.

Now, as the visible line on a plane surface makes known to the mind the place of the mathematical line not visible, so the thin sheet of paper in contact with a plane surface makes known to the mind the place of the plane not visible, and the sheet of paper may be referred to as the plane, in the same manner that the visible line is referred to as the line.

With this understanding the sheet of paper on the metal surface, the plane of which is at right angles to the axis line of the central rod, will be referred to as the *central part* of the plane of the earth's orbit.

Any lines drawn on that surface from the centre or otherwise are to be considered as in the plane of the earth's orbit, and as the lines in that plane can be considered as extended indefinitely in extent in all directions, so the plane can be considered as extended in all directions.

It is of interest to note that when the astronomers, at the time of Copernicus, lost the imaginary advantage of making their observations from a *motionless* body, the fact of the motion of the earth round the centre of the sun in a plane passing through the centre of the sun, determined the great plane of reference in the new and true system; and the fact of the rotation of the earth determined by the incident of equal night and day at the same two places in the earth's orbit, determined the line of reference in the plane of reference, the line from the centre of the earth at the day of equinox to the centre of the sun.

This line is marked on the plane of the earth's orbit as the line of equinox.

Thus are presented in the instrument, in connection with the great centre of reference, the plane of reference and the line of reference, and by these means can be defined the relative position of any line from the centre of the sun to any object in space.

Thus I have endeavored to lead the mind to the conception that the plane of the earth's orbit in the instrument is *parallel* to the plane in which the earth is in motion round the sun. To this is to be added that in reference to the vast distances to the fixed stars, the plane of the earth's

orbit on the instrument may be considered without any error as in the plane in which the earth moves round the sun, as on the scale of the instrument the distance from the place of the instrument to the centre of the earth is less than $\frac{1}{2000}$ of an inch.

With this conception of the position in space held by the earth's orbit in the instrument, conceive also that there is nothing intervening between the instrument and the heavens, and that the night is clear, it would be seen that by extension of the plane as presented to the stars, it would pass through certain constellations which could be named, and is in known relation to certain fixed stars which could be named, thus defining its position in space by reference to stars holding a fixed position in space.

Thus you would rise to the first great conception as to the relative position of bodies in the universe. All space would be divided by the plane of the earth's orbit into two great halves, and bodies would be defined in position by reference to the great plane, each body would be in space either north of the plane, or south of the plane, or in the plane.

ANGLES OF LONGITUDE AND LATITUDE.

If the line to the object is in the plane of the earth's orbit, it will be seen by reference to the plane in the instrument that it is at a certain angle with the line of equinox, the line of reference in the plane, from the same point.

THE CIRCLE OF DEGREES OF LONGITUDE.

To present the angles made with the line of equinox, a circle of degrees having its centre at the centre of the sun is drawn on the plane of the earth's orbit, the degrees being marked from the line of equinox.

Thus when the line to a body from the centre of the sun crosses the line of degrees, at the mark 30 degrees, the position of that line is known by its angle of 30 degrees.

The angles with the line of equinox are called *angles of longitude*, and the circles of degrees the circle of degrees of longitude.

If the line to the object be above the plane of the orbit of the earth, it is at a certain angle with that plane.

To present that angle a line is drawn in the plane of the earth's orbit, presenting the line in which a plane passing through the line to the object and intersecting the plane of the earth's orbit at right angles ; that line is called the *line of intersection.*

The angle made by the line to the object with its line of intersection defines the relation of the line to the plane of the earth's orbit ; that angle is called the angle of latitude ; north latitude of the object is north, south latitude of the object is south, and the angle made by the line of intersection with the line of equinox is the angle of longitude of the line to the object, always reckoned eastward.

To present the angles of latitude and longitude on the instrument there is provided a steel wire, which can be adjusted to extend from the centre of the sun at an angle of $16\frac{1}{2}^\circ$ with its line of intersection in the plane of the earth's orbit and its line of intersection at an angle of $112\frac{1}{2}^\circ$ with the line of equinox, thus presenting the line to a star, whose latitude is $16\frac{1}{2}^\circ$ N, and longitude $112\frac{1}{2}^\circ$ E., the latitude and longitude of the star Castor in the constellation of the Twins.

In the same manner can the steel wire be adjusted to present the latitude and longitude of any star within certain limits that are allowed by the construction of the instrument.

DISTANCE TO THE FIXED STARS.

Next as to the distances to the fixed stars. They cannot be presented in the instrument, as the distance to the nearest star, Capilla, is 224,000 times the distance from the earth to the sun. By reference to the instrument some relative idea can be given of this vast distance.

The distance from the earth to the sun, as presented on the scale of the instrument and in the instrument, is 11½ inches; 11½ multiplied by 224,000, the product expressed in miles is 40 miles. Thus the distance to the *nearest* fixed star is 40 miles on the scale, which presents the sun at a distance of 11½ inches.

The distances to only 12 of the fixed stars are known. The reason of this limitation could be readily given, but time does not permit.

SOLAR SYSTEM.

Next as to the solar system as is known to the eye, without the aid of the telescope.

It is presented in the instrument by the centre of the sun, and the centres of the planets of Mercury, Venus, Earth, Mars, Jupiter and Saturn in the simplicity in which they exist in space and by points as they are seen in the heavens. Each planet is presented in its true distance from the sun on the scale of the instrument, is movable in its plane as its known angle with the plane of the earth's orbit; the position in space of each plane is defined by the longitude of its line of intersection with the plane of the earth's orbit, marked on the plane in the instrument as its *line of nodes.*

To make known where the point that represents the centre of a planet is, there is placed over the point a small

ball indicating the place of the point. An elastic thread is stretched from the centre of the sun to the centre of the planet. This thread crosses the circle of degrees of longitude, thereby making known the longitude of the planet at that place in its orbit.

The motion in longitude each 24 hours of each planet is known.

Each planet can be placed at its known longitude on any given day, say 21st March, 1882. That being done and duly observed, each planet can be moved to the place it will be in at the end of any time, say 30 days. Multiply the sum in degrees of the motion of the planet in 24 hours by 30, the product will be the motion in degrees in 30 days; add that product to the degrees in longitude on 21st March, the sum is the position in longitude at the end of 30 days. Place the planet at that position in longitude.

In the same manner place each of the planets in its new position at the end of 30 days. Having carefully noted the relative positions of the 6 planets, carry forward each planet in a 30 days' movement to a new position; repeat this many times, and there will be a personal knowledge of the solar system that cannot be attained in any other way. Add to that, what time does not permit me to do, the designation of the several relations determined by position, and the knowledge is in a great degree complete.

CENTRE OF THE EARTH AND AXIS LINE OF ROTATION.

The next centre of reference used by the astronomer is the *centre of the earth.* The position of that centre and its motion, both in reference to the centre of the sun, has been defined and presented.

The plane of reference for lines from the centre of the

earth, is the plane of the equator, a plane in which are the line of the equator and the centre of the earth.

To that plane the axis line of rotation, called the axis of the earth, is at right angles.

That axis line passing through the centre of the earth is at the angle of 66½° with the plane of the earth's orbit, in which is the centre of the earth. As the centre of the earth moves in its orbit, the axis moves with it, but its successive positions are parallel positions, the line being continuously at an angle of 66½° with the plane of the earth's orbit. The relations thus described are presented by means of what is called the Pendulum Combination.

PENDULUM COMBINATION.

Time does not permit the description in detail of this combination. The pendulum which I hold in my hand has at its top the suspension tube, by which the pendulum is suspended at one end of the arm A from a rod, at right angles to the arm A. The pendulum weight carries a long tube-bearing, the centre line of which, when the pendulum is in place and free to hang in its vertical plane, is at an angle of 66½° with the plane of the earth's orbit, or at an angle of 23½° (90°–66½°) with its suspension rod, which rod is at right angles to the plane of the earth's orbit.

In this inclined tube-bearing I place a steel rod. That rod is then in the plane of the suspension-bearing and the centre of gravity of the pendulum weight, and is at an angle of 66½° with the plane of the earth's orbit. The centre line of the suspension-bearing extended intersects the rod in the inclined bearing in a point that is 11½ inches from the centre of the sun, and the line from that point to the centre of the sun is at right angles to the axis line of

revolution of the centre of the earth ; the point therefore represents the centre of the earth. The position of the point is indicated by a circular cut on the rod.

I place on this circular cut the loop of an elastic thread, and stretching the thread I place the other loop on the circular cut, the point at the centre of which indicates the position of the centre of the sun in the instrument.

THE ALTERNATING ANGLES OF THE LINE FROM THE CENTRE OF THE SUN AND THE AXIS LINE OF THE EARTH.

I place the arm A in an horizontal position. I wish that every eye in this audience were near enough to apprehend clearly the remarkable presentation that follows. There would be seen a line from the centre of the sun to the centre of the earth, at *right angles* to the axis line of rotation, of necessity the place of the earth in its orbit when *night is equal to day.* This is therefore the place of the earth at the spring equinox. As I move the arm A downward, and the centre of the earth has its eastward motion, it will be seen that the angle 90°, the right angle, becomes less and less than 90°, until, at the end of a quarter revolution, the angle is $66\frac{1}{2}°$ ($90°-23\frac{1}{2}°$), the place of the summer solstice, occurring in June, continuing the revolution another quarter, the angle increases from $66\frac{1}{2}°$ to 90° ; at the place of the fall equinox, occurring in September, continuing the revolution, the angle continues to increase to $113\frac{1}{2}°$ ($90°+23\frac{1}{2}''$) ; at the place of the winter solstice, occurring in December and completing the revolution by another quarter, the angle decreases to 90°, when the earth is again at the spring equinox.

PARALLEL POSITIONS OF THE AXIS LINE AS THE EARTH MOVES IN REVOLUTION.

It will be seen that at all the places of the revolution the axis line holds parallel positions.

The instrument is provided with the parts that show in detail that in these changes in angle of the angles made by a line to the centre of the earth in the axis line, from the centre of the sun are presented the causes of all the phenomena of light and heat, of the seasons, of the changes in length of day and night, etc., etc.

The time at my command makes necessary this statement out of its place.

If the instrument, being of the construction and adjusted to the position described, was in the open air, it would be seen that the axis line is always *in line* to the *North Star* at all places of the earth in its orbit, thus confirming the truth of the position of the instrument.

THE CENTRE OF THE EARTH ANOTHER CENTRE OF REFERENCE—THE PLACE OF THE PLANE OF THE EQUATOR, ITS PLANE OF REFERENCE, AND LINE PARALLEL TO LINE OF EQUINOX—ITS LINE OF REFERENCE.

The plane in which, as has been said, is the centre of the earth and the equatorial line is at right angles to the axis line.

I present that plane to the eye when I place a tube in the axis line rod, carrying a metal plate, on which is a thin sheet of paper, the plate holding the position at which the centre of the earth is in the sheet of paper. I place the arm A in a horizontal position, and then the line of equinox in the plane of the earth's orbit extended passes through the centre of the earth, and the line of equinox will be in

the plane of the equator, as well as in the plane of the earth's orbit.

As the axis line of the earth is at an angle of $23\frac{1}{2}°$, with a line at right angles to the plane of the earth's orbit, and as the plane of the equator is at right angles to the axis line, therefore, the plane of the equator is at an angle of $23\frac{1}{2}°$ with the plane of the earth's orbit; as is, in fact, the relation of the two planes in space.

The plane of the equator has fixed connection with the pendulum, and, therefore, when the earth is moved in revolution the plane of the equator moves parallel to itself, and all the successive positions of the line of equinox in the plane of the equator are parallel positions.

HOURS OF RIGHT ASCENSION.

It will be seen that on the plane of the equator is a circle of figures, 1 to 24, at equal distances, the figures being counted from the line of equinox.

The numbers indicate hours of right ascension. The meaning of the name and the manner in which they are used to determine position will be explained presently. Their use will be described now.

Lines to objects in space from the centre of the earth are either in the plane of the equator or north or south of the plane.

If in the plane the line to the object will cross the hour circle at a certain hour and parts of an hour. Suppose the line crosses at 3 hours. Then it is said the right ascension of that object is 3 hours.

The line to another object crosses at $5\frac{1}{2}$ hours. Then it is said that the right ascension of that object is $5\frac{1}{2}$ hours.

ANGLES OF DECLINATION.

But if the line to the object is north or south of the plane of the equator, then it is at a certain angle with that plane. That angle is determined in the same manner as the angles of latitude already described, but a different name is given to it.

The angles made by lines from the centre of the earth to objects in space not in the plane of the equator, are called angles of declination, north or south, as the case may be, then the reference to the line of equinox is by the hours of right ascension.

To present an example of a line to a certain star, the declination north and the hour of right ascension being known, there is provided a rod which can be connected with the plane of the equator at hour 7½, and which carries a steel wire. The rod and the wire can be so adjusted in position higher or lower, that the wire points to the centre of the earth, and is at an angle of 39½° with its line of intersection. The steel wire then is the line to an object whose angle of declination north is 39½°, and hour of right ascension is 7½ hours. That object is the star Castor in the constellation of the twins (Gemini).

The line to the same star from the centre of the earth, is already presented in connection with the plane of the earth's orbit.

Observe these two lines are parallel. I move the arm A in revolution, it will be seen that at all places of the earth in its orbit the two lines continue parallel, and for the reason that in relation to the distance to the star Castor on the scale of the instrument exceeding 40 miles, we know not how much, the created change in position of the point

representing the earth (less than 2 feet) has no influence on the angles that can be observed by existing instruments.

It will be readily understood that the position of any star can be presented by its angle of declination and hour of right ascension, in the manner that has just been described.

LINES TO THE FIXED STARS FROM A PLACE OF OBSERVATION ON THE SURFACE OF THE EARTH IN THE PARALLEL OF 40° N.

Next is to be presented the line to a fixed star from a place of observation in a known parallel of latitude on the surface of the earth: the parallel taken is 40° N., very nearly the parallel of the city of New York.

The plane of reference of lines from a place of observation in the parallel of 40° N. is the plane tangent to the surface of the earth at the place of observation in the parallel of 40° N., and the line of reference is the line in that plane passing through the place of observation—that is, parallel to the line of equinox in the plane of the equator.

Now, this plane of observation, the plane tangent to the surface of the earth in the parallel of 40° N., is presented in the instrument, although the earth on the scale of the instrument is only $\frac{1}{1000}$ of an inch in diameter, which is shown as follows:

Divide 8,000, the diameter of the earth in miles, by 8,000,000 (the distance in miles represented by one inch on the scale of the instrument), the quotient $\frac{1}{1000}$ of an inch is the diameter of the earth in *the scale of the instrument.*

A place of observation in the parallel of 40° N. on a globe

$\frac{1}{1000}$ of an inch in diameter is at less than $\frac{1}{2000}$ of an inch from the centre of the globe.

Therefore the point presenting the centre of the earth, and a place of observation in the parallel of 40° N., cannot be distinguished by the eye from each other; and lines from a point representing the centre of the earth may be taken without error as representing lines from any point on its surface.

It is easily shown that the plane tangent to the surface of the earth in a certain parallel of latitude, when extended until it intersects the axis line of the earth, intersects the axis line at an angle the same as the angle of latitude of that parallel, and that this relation is constant for a certain latitude whatever be the diameter of the sphere taken to represent the earth. Therefore a plane intersecting the axis line at the centre of the earth at an angle of 40° with the axis line, may be taken to represent the plane tangent at the parallel of 40°, as the parallel planes through the two points are so nearly together that they cannot be seen separately.

I place in the inclined bearing in the pendulum an axis line rod, carrying at its top a metal plate. The point at the centre of the plate is 11½ inches from the centre of the sun, and a line from it to the centre of the sun, is at right angles to the axis line of revolution of the earth; that point, therefore, truly presents the centre of the earth in the axis line.

On the metal plate is a thin sheet of paper, that sheet of paper presents the *plane* of that metal plate; the centre of the earth is in that plane, and the plane is at an angle of 40° with the axis line, then that plane may be taken, and

is taken as presenting in the instrument the plane of observation in the parallel of 40°, and the plane is so marked.

The plane of observation being carried by the axis rod, and that rod having the motion of rotation of the earth, the plane of observation moves in rotation in common with the earth. Its position by motion is defined by the hours of rotation, determined by reference to the sun at midday.

To present these hours in the instrument, there is carried by the same axis line rod, an hour circle presenting the two sets of 12 hours each, hours P.M. and hours A.M. The hours are counted and marked from the midday line. The hour hand of the hour circle is carried by the plane of observation.

A plane at right angles to the plane of observation and that passes through *its centre* and through *the axis line of the earth* (presented in the instrument by the centre line of the axis line rod) is called the *meridian plane* of the place of observation. At the intersection of that plane with the plane of observation is the hour hand of the hour circle of hours of rotation.

The hour circle, A. M., P. M., has motion due to the motion of the centre of the earth *in revolution ;* the hour *hand* has motion due to the motion of the plane of observation in rotation, and, therefore, the hour circle needs at each place of the earth in its orbit to be adjusted to the midday line to indicate correct time of occurrences at each place of the earth in its orbit.

There is another hour circle, that has reference only to the rotation of the earth, which is determined in position by an observation of a star in reference to which the earth has no motion to the unaided eye except that due to rotation. For this hour circle the time of one rotation (a time

in which no change is or ever has been known) is divided into 24 hours.

HOURS OF RIGHT ASCENSION DETERMINED BY USE OF AN ASTRONOMICAL CLOCK.

The astronomer has knowledge of these hours by the use of an astronomical clock, carrying on its face 24 hours, regulated as nearly as may be to present 24 hours is one rotation, with the rate of loss or gain ascertained by infinite care, the correct time can be known by the clock.

It is by the use of this clock, and of an instrument known as the transit instrument, that the astronomer determines the relative positions of the stars as seen from the surface of the earth. The hours so noted are called hours of right ascension.

To refer to these hours in the instrument there is provided a circle of right ascension hours which count from the line of equinox. The hours are in position to be referred to, and the hour hand, carried by the plane of observation in the plane of the meridian of the place of observation, is also the hour hand of the hours of right ascension.

Having the plane of observation in place and movable in rotation, and moving in revolution when the centre of the earth is moved in revolution, and the hour circle of hours of right ascension in its fixed relation to the line of equinox, the instrument is adjusted to present the observations by which the relative position of the fixed stars from the place of observation is defined, the plane of observation, or the plane of the equator, being the plane of reference.

The instrument of observation is known as the transit instrument. This instrument is constructed, mounted and adjusted to observe angles *only* in the meridian plane of the instrument.

Its telescope can only be changed in position in a vertical plane.

Conceive the astronomer to be at the place of observation, prepared to make observations through the telescope of a transit instrument, having the astronomical clock at hand, but not in motion, the hands of the clock set at 0 hours 0 minutes 0 seconds, and that at the instant that the meridian plane of the transit instrument passes through the line of equinox the clock is put in motion and the astronomer begins his observation.

The movement of the earth in rotation carries the astronomer and his instrument eastward, and as each star is observed in the meridian plane and the centre line of the instrument is directed to the star, two observations are made: First, the culminating angle of the star; second, the time by the astronomical clock of that culmination.

The instrument is provided to show the culminating angle, the plane of observation being the plane of reference, and the culminating angle the plane of the equator being the plane of reference.

The astronomical clock gives the time of the culmination. The time is expressed in hours and parts of an hour.

Thus the relative position of the fixed stars is in part defined by *the time* in which the observer by instrument is carried from a known position to the position at which the star is seen in the meridian of the observer, and therefore, at its culminating angle, a time determined by a clock and called hours of right ascension. The expression used might be time distance.

The instrument is now ready for the study by the individual student of the solar and stellar system by observations, made by the use of the instrument.

THE SOLAR SYSTEM SEEN EDGEWISE FROM THE SURFACE OF THE EARTH.

One general fact is readily presented, viz: that the solar system is seen from the surface of the earth *edgewise.* This fact, in connection with the mistaken though confident belief that the earth, the place of observation, was an entirely motionless body, was the origin of the erroneous astronomical ideas that had possession of school and church for centuries before the time of Copernicus.

Take as an example the planet Venus, now known by the student as a planet moving continuously and at more nearly uniform rate than any other planet in one direction in a well-defined plane.

As looked for from the surface of the earth for many nights it is not seen at all, and when seen, only seen as an evening star or as a morning star, seen at times as stationary and at times moving in one direction, at times in another direction.

A few minutes observation of the movement of Venus in the instrument make all that is seen from earth, entirely consistent with the well-known motion of Venus through space.

As the instrument now stands it can be used to present to the eye whatever can be observed from the parallel of 40° N. in all places of the earth in its orbit, in relation to sun, planet or star.

The character of the observation will be presented by reference to the sun and to the planet Venus.

For this purpose I place the arm A. in an horizontal position, the earth in longitude 180°, and place the planet Venus at longitude 30°.

I adjust the hour circle by its midday line to the meri-

dian plane, when the meridian plane passes through the centre of the sun.

I draw the fine thread from the place of observation to the centre of the sun. The angle made by that line with the place of observation (50°) presents the angle at which light and heat are received by the surface of the earth at the place of observation in the parallel of 40° N.

I move the plane of observation slowly eastward, the angles of the sun's altitude, indicated by the angle of the line to the sun with the plane of observation, are seen to become less and less, and when the line to the sun coincides with the plane of observation, the occurrence of the *evening* sun takes place, and at the next movement of the plane in rotation, the sun is *shut out* of sight.

I note by reference to the P. M. hour circle that the time is 6 P. M.

I continue the motion in rotation of the plane of observation and soon its meridian plane passes through the centre of the sun, but the plane is turned away *from* the sun, and it is the occurrence of midnight.

I continue the motion of the plane in rotation eastward, and it comes to the position at which the line to the sun coincides with the plane of observation, and at the next movement of the plane in rotation the sun is disclosed to sight, and the occurrence of the *morning* sun takes place.

The time by the A. M. hour circle, it is 6 A. M. Thus it is observed that the hours of darkness are from 6 P. M. to 6 A. M.

Next I move in rotation the plane of observation to the position at which the meridian plane passes through Venus in longitude 30°.

By observations of the same character as those made in reference to the sun, are ascertained the hours at which

Venus is *first* and *last* in the line of sight. The hours are 6.30 A. M. and 7 P. M. and thus it is observed that at the place of the earth in its orbit, Venus is in the line of sight from 6.30 A. M. to 7 P. M. On comparing this time with the hours of darkness it is known that from 6.30 A. M. to 7 P. M. Venus is visible, and Venus is seen as an evening star.

After these determinations the earth and Venus may be considered to continue their motion in their orbit lines for the same number of days to new positions in longitude, the earth's motion being at .98° and Venus at 1.61° each day, or, for convenience of calculation, the earth at 1° and Venus at 1.6°, for any successive number of days, and at their new places in longitude, the observations are to be made that determine during what hours Venus is visible and when visible, whether seen as a morning or evening star.

THE TRANSIT OF VENUS IN 1882.

The recent phenomena of Venus seen moving over the surface of the sun is a well-timed example of what can be made plain in cause and calculation to a certain extent that is availed of as follows:

Once in each revolution of the earth the earth is in the longitude of 75°—more precisely, 74.1°—and once in each revolution of Venus Venus is in longitude of 75°, and is then *in the plane of the earth's orbit.* Once in very many years it occurs that the earth and Venus are at the longitude 75° so nearly at the same time that Venus is in line between the sun and certain points in the earth's surface, and therefore in this relative position Venus will be seen, by observers at certain points on the surface of the earth,

to pass over the surface of the sun, because the motion of Venus in its orbit is at 1.6°, while the earth moves at 1°.

The instrument can be used to present the essential character of the calculation by which the time of a transit of Venus is determined.

The following calculation is not decimally correct, nor does it include all necessary to define precisely the time, places, etc. In March, 1882, the earth being at longitude 180, Venus was at longitude °.

The earth's motion taken for convenience of calculation at 1° per day, and the motion of Venus taken at 1.6° per day, it is a simple algebraic problem to determine the time at which the earth and Venus will be in the same longitude. The answer is at 75°.

That this answer is correct is known as follows:

Earth's movement from 180° to 75° is 180 + 70 = 255; motion of Venus to motion of the earth 1.6° to 1°.

Therefore Venus moves 408° while the earth moves 255. To the longitude of Venus ° add 408° and Venus is at longitude 75°, at the same time the earth is at 75°, and thus at that longitude the transit occurs. The earth and Venus were in that relative position Dec. 6, 1882, when Venus was in line between the surface of the sun and certain places on the surface of the earth. As soon as in line it is seen as if on the surface of the sun, the sun is stationary.

COMPREHENSIVE STATEMENT OF THE CAPACITY OF THE INSTRUMENT.

I close these remarks explanatory with the comprehensive statement.

That the sun, planet and star instrument being in position and adjustment as described, the earth may be placed at *any* place in its orbit, and the hour circle being at its

midday point for that place of the earth, and the five planets and one selected star being at their places in longitude—these can be determined by observation by the use of the instrument.

1. The time by the hour circle A. M. P. M. at which the sun, each of the five planets and the selected star are first and last in the line of sight, and therefrom can be determined the hours of declination, and the hours during which each planet and the selected star, if visible at all, will be visible.

2. That if the earth be considered as having moved to a new place of longitude, each of the five planets can be moved to its place in longitude in the same line and the selected fixed star will remain in its place in longitude which it never leaves.

3. That at the new places in longitude the same facts can be determined.

4. That a succession of observations of this character is at the command of the student.

PRESENTATION NOT ON SCALE, BUT BY USE OF 5-INCH GLOBE CARRIED BY PENDULUM COMBINATION, AND OF LINE PARALLEL TO LINE FROM THE CENTRE OF THE SUN TO CENTRE OF THE EARTH, PRESENTING THE CAUSES OF ALL THE PHENOMENA OF LIGHT AND HEAT AS OBSERVED ON THE SURFACE OF THE EARTH.

In addition to the presentation on a scale of the great facts of astronomical knowledge, there is provided for use, in connection with the centre of the sun and the plane of the earth's orbit, a 5-inch terrestrial globe, carried by the pendulum combination, presenting the plane of observation in the parallel of 40° N., and there are provided the

parts that present a line parallel to the line from the centre of the sun to the centre of the earth, that can be adjusted to point to any place on the surface of the globe, whereby are presented the angles at which light and heat are received by the surface of the earth in any parallel, at different positions of the earth's rotation, and at different places of the earth in its orbit, among which are day and night, different length of day and night, different quantities of heat received by the same surface at different places of the earth in its orbit, and therewith the change of the seasons; and can be readily presented the fact, that by the movement of the earth in revolution round the sun, one rotation of the earth is lost when rotations are counted by reference to the sun.

All facts to be readily apprehended by an intelligent and attentive use of the eye.

MOON INSTRUMENT.

In connection with the sun, planet and star instrument, are instruments presenting on a scale, as to dimension as well as distance (except of the sun and distances to the sun), the moon in its relations to the earth, its motion round the earth in a line, the resultant of the two causes determining the moon's position in space.

The body of rays from the sun illuminating one-half of the surface of the earth, and the shadow of the earth as projected in space, which presents the causes of an eclipse of the sun, when the moon enters the body, or part of the body of illuminating rays; and the causes of an eclipse of the moon enters the shadow, or part of the shadow of the earth.